

**NONPROVISIONAL PATENT APPLICATION**

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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**BOX PATENT APPLICATION**

**NONPROVISIONAL APPLICATION TRANSMITTAL  
RULE §1.53(b)**

Director of the U.S. Patent and Trademark Office  
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Sir:

Transmitted herewith for filing under 37 C.F.R. §1.53(b) is the nonprovisional patent application

For (Title): MULTILAYER FLEXIBLE WIRING BOARDS AND PROCESSES FOR  
MANUFACTURING MULTILAYER FLEXIBLE WIRING BOARDS

By (Inventors): Hideyuki KURITA, Hiroyuki HISHINUMA

Formal drawings (Figs. 1-10C; 9 sheets) are attached.  
 A Declaration and Power of Attorney is filed herewith.  
 An assignment of the invention to SONY CHEMICALS CORP. is filed herewith.  
 An Information Disclosure Statement is filed herewith.  
 Entitlement to small entity status is hereby asserted.  
 A Preliminary Amendment is filed herewith.  
 Please amend the specification by inserting before the first line the sentence --This nonprovisional application claims the benefit of U.S. Provisional Application No.       , filed       .  
 Priority of foreign application No. JP 11-294686 filed October 18, 1999 in Japan is claimed (35 U.S.C. §119).  
 A certified copy of the above corresponding foreign application is filed herewith.  
 The filing fee is calculated below:

**CLAIMS IN THE APPLICATION AFTER ENTRY OF  
ANY PRELIMINARY AMENDMENT NOTED ABOVE**

| FOR:   | NO. FILED | NO. EXTRA |
|--|-----------|-----------|
| BASIC FEE  |           |           |
| TOTAL CLAIMS   | 15 - 20   | = 0*      |
| INDEP CLAIMS   | 4 - 3     | = 1*      |
| <input type="checkbox"/> MULTIPLE DEPENDENT CLAIMS PRESENTED |           |           |

\* If the difference is less than zero, enter "0".

**SMALL ENTITY**

| RATE    | FEES     |
|---------|----------|
|         | \$ 355   |
| x 9 =   | \$       |
| x 40 =  | \$       |
| + 135 = | \$       |
|         | TOTAL \$ |

**OTHER THAN A  
SMALL ENTITY**

| RATE    | FEES         |
|---------|--------------|
|         | \$ 710       |
| x 18 =  | \$ -----     |
| x 80 =  | \$ 80        |
| + 270 = | \$ -----     |
|         | TOTAL \$ 790 |

Check No. 112807 in the amount of \$790.00 to cover the filing fee is attached. Except as otherwise noted herein, the Director is hereby authorized to charge any other fees that may be required to complete this filing, or to credit any overpayment, to Deposit Account No. 15-0461. Two duplicate copies of this sheet are attached.

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### **Application Information**

Title Line One:: MULTILAYER FLEXIBLE WIRING BOARDS  
Title Line Two:: AND PROCESSES FOR MANUFACTURING  
Title Line Three:: MULTILAYER FLEXIBLE WIRING BOARDS  
Title Line Four::

Total Drawing Sheets:: 9  
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### **Continuity Information**

>This application is a::  
Application One::  
Filing Date::  
Patent Number::  
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### **Prior Foreign Applications**

Foreign Application One:: JP 11-294686  
Filing Date:: October 18, 1999  
Country:: Japan  
Priority Claimed:: yes  
Foreign Application Two::  
Filing Date::  
Country::  
Priority Claimed::  
Foreign Application Three::  
Filing Date::  
Country::  
Priority Claimed::

**MULTILAYER FLEXIBLE WIRING BOARDS**  
**AND**  
**PROCESSES FOR MANUFACTURING MULTILAYER FLEXIBLE WIRING BOARDS**

**5 BACKGROUND OF THE INVENTION**

The present invention relates to the field of flexible wiring boards, particularly to the technique of laminating flexible wiring board pieces into a flexible wiring board of multilayer structure.

10 Recently, multilayer flexible wiring boards are widely used in the field of electronic apparatus. A method for forming a multilayer flexible wiring board involves laminating a plurality of flexible wiring board pieces.

An example of process for laminating two flexible wiring 15 board pieces is explained with reference to the attached drawings as follows. Referring to Fig. 8, the reference 110 represents a flexible wiring board piece used for lamination. This flexible wiring board piece 110 has a base film 117 on which a metal wiring 115 is formed by patterning a copper foil. A resin film 112 is 20 provided on metal wiring 115.

This resin film 112 is thermoplastic, i.e. it is not adhesive at normal temperatures but softens to develop adhesiveness upon heating.

Resin film 112 has a plurality of openings 120 in which a 25 plurality of bumps 121 are provided.

The bottom of each bump 121 is connected to metal wiring 115 while the top projects from the surface of resin film 112.

The reference 130 in Fig. 9 represents a flexible wiring board piece to be laminated to said flexible wiring board piece 110. This 5 flexible wiring board piece 130 has a base film 132 on which a metal wiring 135 is formed by patterning a copper foil, similarly to said flexible wiring board piece 110.

A non-thermoplastic cover film 138 is provided on metal wiring 135 and said cover film 138 has openings 139 at the locations 10 corresponding to bumps 121 of said flexible wiring board piece 110 so that the surface of metal wiring 135 is exposed at the bottom of each opening.

For laminating these two flexible wiring board pieces 110, 130, one flexible wiring board piece 130 is mounted on a table 142 15 with openings 139 upward and opposed to the other flexible wiring board piece 110 with bumps 121 downward (Fig. 10(a)).

Then, the top of bump 121 is contacted with the surface of metal wiring 135 at the bottom of opening 139, and an ultrasonic resonator 145 is pressed against base film 117 of one flexible wiring 20 board piece 110 (Fig. 10(b)).

Ultrasonic resonator 145 is connected to an ultrasonic wave generator not shown, which is activated to transmit ultrasonic wave to ultrasonic resonator 145 pressed against flexible wiring board pieces 110, 130 so that ultrasonic resonator 145 applies ultrasonic 25 wave to flexible wiring board pieces 110, 130. Thus, bumps 121 are

connected to metal wiring 135 in contact with said bumps 121 by this ultrasonic vibration.

Then, these flexible wiring board pieces 110, 130 are heated under pressure so that resin film 112 softens to develop 5 adhesiveness, whereby flexible wiring board pieces 110, 130 are connected via resin film 112 into a multilayer flexible wiring board 150 (Fig. 10(c)).

Thus, the use of ultrasonic resonator 145 eliminates the use of solder to electrically connect flexible wiring board pieces 110, 10 130 by a single ultrasonic application while pressing a plurality of bumps 121 against metal wiring 135.

However, such bumps 121 are formed by a complex copper plating process.

With such an ultrasonic resonator 145 pressed against the 15 whole flexible wiring board pieces 110, 130 to apply ultrasonic wave, connection failure may occur if the heights of bumps 121 are not uniformity. For example, the reference 151 in Fig. 10(c) represents such a connection failure, in which a lower bump 122 is not connected to metal wiring 135 because of lack of contact 20 with metal wiring 135 during ultrasonic application in contrast with a higher bump 121 connected to the surface of metal wiring 115.

Bumps 121 should have a uniformity of height within  $\pm 3 \mu\text{m}$  or less to efficiently connect flexible wiring board pieces 110, 25 130, but this is difficult when bumps 121 are formed by

electroplating as described above.

Moreover, bumps 121 should fill openings 120 and project from the surface of resin film 112 by growing copper to a thickness of 40  $\mu\text{m}$  or more, but it takes one hour or more to attain such a thickness 5 by electroplating, resulting in increase of production costs.

An object of the present invention is to obtain a multilayer flexible wiring board from flexible boards at low cost with high yield to overcome the disadvantages of the prior art described above.

10

#### **SUMMARY OF THE INVENTION**

In order to attain the above object, the present invention provides a process for manufacturing a multilayer flexible wiring board by laminating flexible wiring board pieces having a base film 15 including a resin film and a metal wiring provided on said base film, said process comprising applying ultrasonic wave to said metal wirings of said flexible wiring board pieces to be laminated in close contact with each other at their surfaces to bond said metal wirings.

20

The present invention also provides a process for manufacturing a multilayer flexible wiring board by bonding metal wirings of at least two flexible wiring board pieces having a base film including a resin film and a metal wiring provided on said base film, said process comprising contacting the tip of ultrasonic 25 resonator with the exposed opposite side of a portion to be bonded

of said metal wirings of at least one flexible wiring board piece in two flexible wiring board pieces to be bonded, and applying ultrasonic wave to said ultrasonic resonator to bond said two metal wirings to be bonded.

5       In the process for manufacturing a multilayer flexible wiring board of the present invention, ultrasonic wave is applied to said metal wirings in close contact with each other at their surfaces while a thermoplastic resin layer developing adhesiveness upon heating is placed between said metal wirings.

10      In the process for manufacturing a multilayer flexible wiring board of the present invention, said metal wirings are ultrasonically bonded and then heated to laminate said flexible wiring board pieces by the adhesion of said thermoplastic resin.

15      In the process for manufacturing a multilayer flexible wiring board of the present invention, a metal coating selected from a metal coating based on gold, a metal coating based on silver, a metal coating based on nickel, a copper-nickel alloy coating, a coating based on aluminium, a coating based on titanium and a solder coating is preliminarily formed on at least one of the surfaces 20 of the parts of said metal wirings to be ultrasonically bonded before said metal wirings are ultrasonically bonded.

      In the process for manufacturing a multilayer flexible wiring board of the present invention, ultrasonic wave is individually applied to the parts of said metal wirings to be bonded.

25      The present invention also provides a multilayer flexible

wiring board formed by laminating at least two flexible wiring board pieces having a base film and a metal wiring provided on said base film, wherein at least one flexible wiring board piece has a cover film including a resin film on said metal wiring and a first opening 5 is provided on said cover film, and said metal wiring exists at the bottom of said first opening so that said metal wirings of said flexible wiring board pieces are bonded to each other by applying ultrasonic wave while the part of said metal wiring located at the bottom of said first opening is in close contact with said metal 10 wiring of the other flexible wiring board piece.

In the multilayer flexible wiring board of the present invention, said cover film has insulating properties to prevent said connected metal wirings from contacting with each other except for the part located at said first opening.

15 In the multilayer flexible wiring board of the present invention, said cover film has a thermoplastic resin layer developing adhesiveness upon heating at least on its surface.

In the multilayer flexible wiring board of the present invention, said first opening and said metal wiring located at the 20 bottom of said first opening forms a concave and the part of said metal wiring of the other flexible wiring board piece to be bonded to said concave is convex on said base film.

In the multilayer flexible wiring board of the present invention, said convex part of said metal wiring of the other 25 flexible wiring board piece has an area smaller than that of said

first opening forming said concave.

The present invention also provides a multilayer flexible wiring board formed by laminating at least two flexible wiring board pieces having a base film and a metal wiring provided on said base film, wherein said base film of at least one flexible wiring board piece has a second opening in which said metal wiring exists at the bottom so that said metal wirings are bonded to each other by applying ultrasonic wave while said metal wiring of the other flexible wiring board piece is in close contact with said metal wiring located at the bottom of said second opening.

In the multilayer flexible wiring board of the present invention, said base film has insulating properties to prevent said metal wirings from contacting with each other except for the part located at said second opening.

In the multilayer flexible wiring board of the present invention, at least one of the surfaces of the parts of said metal wirings to be ultrasonically connected has a metal coating selected from a metal coating based on gold, a metal coating based on silver, a metal coating based on nickel, a copper-nickel alloy coating, a coating based on aluminium, a coating based on titanium and a solder coating.

In the multilayer flexible wiring board of the present invention, said metal wirings to be connected to each other have the same type metal coating on their surfaces.

According to the present invention as defined above,

ultrasonic wave is applied to metal wirings in contact with each other at their surfaces to eliminate formation of bumps via electroplating, thus reducing failures due to non-uniformity of bump height.

5       A resin film is provided on at least one flexible wiring board pieces to be laminated, and the contact region of the metal wiring is exposed at the bottom of an opening formed in the resin film, whereby the resin film at the opening serves to guide the metal wiring of the other flexible wiring board piece into the opening.

10      In this case, the metal wiring of the other flexible wiring board piece may be convex to fit in a concave formed by the opening to facilitate aligning.

Ultrasonic wave is applied under pressure with an ultrasonic resonator directly pressed against the opposite side of one of metal wirings (portion to be bonded of metal wirings) in contact with each other, whereby ultrasonic wave is individually applied to the contact regions to ensure electric connection between the contact regions.

Said resin film may be formed of a thermoplastic resin to  
20 mechanically connect flexible wiring board pieces by the adhesion of the resin film.

In case of ultrasonic bonding, the condition of bonding of metal coating is depend on the combination of metal materials forming the parts of to be bonded. Table 1 below shows the results  
25 of our investigations on the ultrasonic bonding strength of

combinations of various metals.

Table 1: Relationship between combination of metals and bonding properties

| Al | Be | Cu | Ge | Au | Fe | Mg | Mo | Ni | Nb | Pd | Pt | Re | Si | Ag | Ta | Sn | Ti | W | U | Zr | Pb |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|----|----|
| 2  | 2  | 2  | 2  | 2  | 0  | 2  | 2  | 2  |    | 2  | 1  |    | 1  | 2  | 2  | 0  | 2  | 0 | 1 |    | Al |
|    | 1  | 1  |    |    | 0  |    |    |    |    |    |    |    |    |    |    |    |    |   |   |    | Be |
|    |    | 2  | 2  | 0  | 1  | 1  | 2  |    |    | 1  | 1  |    | 2  | 1  |    | 2  |    | 1 |   |    | Cu |
|    |    |    | 1  |    |    |    |    |    |    | 1  |    |    |    |    |    |    |    |   |   |    | Ge |
|    |    |    | 2  | 0  |    | 2  |    |    |    | 1  |    | 1  | 1  | 2  |    |    | 2  | 0 | 1 |    | Au |
|    |    |    | 0  | 0  | 0  |    |    |    |    | 0  | 0  |    | 0  | 0  |    | 0  | 0  | 0 | 0 |    | Fe |
|    |    |    | 1  |    |    |    |    |    |    |    |    |    | 1  |    |    | 1  |    |   |   |    | Mg |
|    |    |    | 1  | 2  |    |    |    |    |    |    |    |    | 1  |    |    | 1  | 0  |   | 1 |    | Mo |
|    |    |    | 2  | 1  |    | 1  | 1  |    |    | 2  | 1  |    | 2  | 1  |    | 2  | 2  |   |   |    | Ni |
|    |    |    | 1  |    |    |    |    |    |    |    |    |    | 1  |    |    |    |    |   |   |    | Nb |
|    |    |    |    | 2  |    |    |    |    |    | 2  |    |    |    |    |    |    |    |   |   |    | Pd |
|    |    |    |    | 1  |    | 1  |    |    |    |    |    |    | 1  |    |    |    |    |   |   |    | Pt |
|    |    |    |    |    | 1  |    |    |    |    |    |    |    | 1  |    |    |    |    |   |   |    | Re |
|    |    |    |    |    |    | 1  |    |    |    |    |    |    | 1  |    |    |    |    |   |   |    | Si |
|    |    |    |    |    |    |    | 2  | 1  |    |    |    |    | 2  | 1  |    |    |    | 1 |   |    | Ag |
|    |    |    |    |    |    |    | 1  |    |    |    |    |    | 1  |    |    | 0  |    |   |   |    | Ta |
|    |    |    |    |    |    |    |    | 0  |    |    |    |    | 0  | 0  |    |    |    |   |   |    | Sn |
|    |    |    |    |    |    |    |    |    | 2  | 2  |    |    |    |    |    |    |    |   |   |    | Ti |
|    |    |    |    |    |    |    |    |    | 0  |    |    |    |    |    |    |    |    |   |   |    | W  |
|    |    |    |    |    |    |    |    |    |    | 1  | 1  |    |    |    |    |    |    |   |   |    | U  |
|    |    |    |    |    |    |    |    |    |    | 1  |    |    |    |    |    |    |    |   |   |    | Zr |
|    |    |    |    |    |    |    |    |    |    |    | 0  |    |    |    |    |    |    |   |   |    | Pb |

O : No bond  
1 : Weak bond  
2 : Strong bond

In Table 1, "2" means strong bond, "1" means weak bond and

"0" means no bond.

5 In case of the present invention, the bond strength may differ from the results of Table 1, because the parts to be bonded are the surfaces of metal wirings. For example, copper-copper combination shows strong bond in case of wire bonding but resulted in weak bond in the metal coating formed on the surface of metal wirings of flexible wiring board pieces as in the present invention.

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Accordingly, suitable metal coatings formed on the surface of the metal wiring of the present invention include a metal coating based on gold, a metal coating based on silver, a metal coating based on nickel, a copper-nickel alloy coating, a coating based 5 on aluminium, a coating based on titanium and a solder coating. Two of these metal coatings may be chosen and formed on the surfaces of metal wirings to be ultrasonically bonded.

The flexible wiring board piece and the multilayer flexible wiring board of the present invention have property of flexibility.

10

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be explained with reference to the attached drawings, in which:

FIG. 1 (a)-(g) shows a process for manufacturing a flexible 15 wiring board piece for use in a multilayer flexible wiring board of the present invention;

FIG. 2 (a)-(d) shows a process for manufacturing another flexible wiring board piece for use in a multilayer flexible wiring board of the present invention;

20 FIG. 3 (a), (b) shows plan views of the flexible wiring board piece shown in FIG. 1;

FIG. 4 (a), (b) shows plan views of the flexible wiring board piece shown in FIG. 2;

25 FIG. 5 (a)-(d) shows a process for manufacturing a multilayer flexible wiring board of the present invention by combining said

flexible wiring board pieces;

FIG. 6 (a), (b) shows another example of combination of flexible wiring board pieces for manufacturing a multilayer flexible wiring board of the present invention;

5 FIG. 7 (a), (b) shows still another example of combination of flexible wiring board pieces for manufacturing a multilayer flexible wiring board of the present invention;

FIG. 8 shows a flexible wiring board piece of one of example;

FIG. 9 shows a flexible wiring board piece of one of example  
10 used with the flexible wiring board piece shown in FIG. 8; and

FIG. 10 (a)-(c) shows one of the example of a process for manufacturing a multilayer flexible wiring board.

#### **DETAILED DESCRIPTION OF THE INVENTION**

15 Referring to Fig. 1(a), the reference 11 represents a metal foil consisting of a rolled copper foil having a thickness of 12  $\mu\text{m}$ . A polyimide precursor solution (the polyimide precursor solution here is a polyimide adhesive G101 made by Sony Chemicals Corp.) is initially coated on the top of this metal foil 11 and  
20 dried to form a polyimide precursor layer 14 (Fig. 1(b)).

Then, polyimide precursor layer 14 is patterned by photolithography and etching and then cured by heat treatment to form a patterned base film 12 (Fig. 1(c)). This base film 12 has a thickness of about 20  $\mu\text{m}$ .

25 The reference 15 in Fig. 1(c) represents an opening in base

film 12 and a plurality of such openings 15 are provided at predetermined locations (only one is shown). Metal foil 11 is exposed at the bottom of each opening 15.

Then, a protective film 17 is applied on the top of base film  
5 12 to temporarily close opening 15 (Fig. 1(d)).

When photolithography and etching are performed as such, any etching solution does not enter opening 15 and metal foil 11 is patterned to form a metal wiring body 18 (Fig. 1(e)). The reference 10 16 represents a gap separating metal wiring bodies 18.

Then, protective film 17 is removed (Fig. 1(f)) and the assembly is electroplated in a plating solution to form a metal coating 26 on the surface of metal wiring body 18 exposed at the bottom of opening 15 and on the surface of metal wiring body 18 exposed on base film 12, whereby a metal wiring 19 comprising metal 15 wiring body 18 and metal coating 26 is obtained. Metal coating 26 here is a gold coating.

The reference 10 in Fig. 1(g) represents a flexible wiring board piece having metal coating 26.

Fig. 3(a) shows a plan view of this flexible wiring board  
20 piece 10 on the side of base film 12. Fig. 3(b) shows a plan view on the side of metal wiring body 18.

As shown in Fig. 3(a), (b), this metal wiring body 18 has a wide patterned contact region 18<sub>1</sub> and a narrow interconnecting line 18<sub>2</sub>.

25 Contact region 18<sub>1</sub> is used for connection to another flexible

wiring board piece as described below. Interconnecting lines 18<sub>2</sub> are distributed on base film 12 to electrically connect contact regions 18<sub>1</sub>.

When flexible wiring board piece 10 is viewed from the side 5 of base film 12, opening 15 in base film 12 is located on contact region 18<sub>1</sub> and opening 15 is smaller than contact region 18<sub>1</sub> (Fig. 3(b)).

Thus, the outer periphery of contact region 18<sub>1</sub> is in close contact with base film 12 to obstruct opening 15 going through base 10 film 12. Contact region 18<sub>1</sub> is provided on base film 12, whereby the surface of contact region 18<sub>1</sub> is raised on the surface of base film 12.

Next, a process for manufacturing the other flexible wiring board piece to be combined with said flexible wiring board piece 15 10 is explained below.

Fig. 2(a) shows a wiring board piece in the state shown in Fig. 1(f), i.e. metal wiring body 18 has been formed and then protective film 17 has been removed.

Starting from the state shown in Fig. 2(a), a polyimide 20 precursor solution is coated on the top of metal wiring body 18 and dried to form a polyimide precursor layer 32 (the polyimide precursor solution here is a polyimide adhesive G101 made by Sony Chemicals Corp.).

Then, polyimide precursor layer 32 is patterned by 25 photolithography and etching and then imidated by heat treatment.

The reference 33 in Fig. 2(c) represents a resin film formed by imidation of polyimide precursor layer 32 and having an opening 34 formed by patterning. This resin film 33 is thermoplastic, i.e. it develops adhesiveness upon heating. Resin film 33 here has a 5 thickness of 14  $\mu\text{m}$ .

In this state, the top surface and bottom surface of metal wiring body 18 are exposed at the bottom of opening 34 of resin film 33 and at the bottom of opening 15 of base film 12. When the assembly is electroplated as such, a metal coating 26 is formed 10 at the exposed part of metal wiring body 18 to form a metal wiring 19. The reference 30 in Fig. 3(d) represents a flexible wiring board piece having metal coating 26 consisting of a gold coating here as described above.

Fig. 4(a) shows a plan view of this flexible wiring board 15 piece 30 on the side of resin film 33. Fig. 4(b) shows a plan view on the side of base film 12.

Also in this flexible wiring board piece 30, metal wiring body 18 consists of a wide contact region 18<sub>1</sub> and a narrow interconnecting line 18<sub>2</sub>.

20 Metal coating 26 is formed and exposed at the part of contact region 18<sub>1</sub> located at the bottoms of openings 34, 15.

However, metal coating 26 is not formed on the surface of interconnecting line 18<sub>2</sub>, contrary to flexible wiring board piece 10 shown in Fig. 1(e) because of electroplating in the presence 25 of resin film 33.

Contact region 18<sub>1</sub> of this flexible wiring board piece 30 is larger than openings 34, 15 in resin film 33 and base film 12 so that the periphery of contact region 18<sub>1</sub> is inserted between resin film 33 and base film 12 to separate openings 34, 15.

5 A process for laminating two flexible wiring board pieces 10, 30 as described above is explained below.

Referring to Fig. 5(a), one flexible wiring board piece 30 of said two flexible wiring board pieces 10, 30 is mounted on a table 35 and opposed to the other flexible wiring board piece 10 in such a manner that opening 34 in resin film 33 of flexible wiring board piece 30 on table 35 faces upward opposite to contact region 18<sub>1</sub> of metal wiring body 18 provided on base film 12 of flexible wiring board piece 10.

Opening 34 in resin film 33 of flexible wiring board piece 30 on table 35 forms a concave with contact region 18<sub>1</sub> and metal coating 26 provided at the bottom of said opening, while contact region 18<sub>1</sub> of opposite flexible wiring board piece 10 forms a convex on base film 12.

Opening 34 forming a concave here is smaller than contact region 18<sub>1</sub> at the bottom of said opening 34 to leave resin film 33 at the periphery of contact region 18<sub>1</sub>. The reference 27 in Fig. 5(a) represents the part of resin film 33 overlying contact region 18<sub>1</sub>.

Then, two flexible wiring board pieces 10, 30 are superposed 25 so that the part 27 overlying contact region 18<sub>1</sub> of resin film 33

serves to guide convex contact region 18<sub>1</sub> into opening 34 forming a concave.

The height S of resin film 33 above contact region 18<sub>1</sub> (the height from metal coating 26 at the top of contact region 18<sub>1</sub>) is smaller than the thickness of metal wiring 19 at convex contact region 18<sub>1</sub> (the sum of the thicknesses of metal wiring body 18 and metal coating 26) so that metal coatings 26 on the surfaces of contact regions 18<sub>1</sub> come into close contact when two flexible wiring board pieces 10, 30 are superposed (Fig. 5(b)).

An ultrasonic resonator 45 of an ultrasonic generator (model 7700A made by Kan Electronics Co., Ltd.) is provided above contact regions 18<sub>1</sub> in close contact with each other and the tip of ultrasonic resonator 45 is brought into contact with the opposite side of contact region 18<sub>1</sub>.

The tip of this ultrasonic resonator 45 is formed in a 100 μm x 100 μm square, which is smaller than opening 15 in base film 12. Thus, ultrasonic resonator 45 is pressed against metal coating 26 on the surface of contact region 18<sub>1</sub> without coming into contact with base film 12 (Fig. 5(c)).

When the ultrasonic wave generator is activated to apply ultrasonic wave under pressure on contact region 18<sub>1</sub> by ultrasonic resonator 45, metal coatings 26 on two contact regions 18<sub>1</sub> are bonded together to electrically connect two flexible wiring board pieces 10, 30.

Then, flexible wiring board pieces 10, 30 are heated under

pressure (at 300 °C for 10 seconds, for example) to mechanically connect flexible wiring board pieces 10, 30 via resin film 33 having developed adhesiveness, whereby a multilayer flexible wiring board 50 according to one embodiment of the present invention is obtained 5 (Fig. 5(d)).

Although only one flexible wiring board piece 30 of two flexible wiring board pieces 10, 30 has thermoplastic resin film 33 in the foregoing embodiment, multilayer flexible wiring board 50 of the present invention is not limited to the case where such 10 two flexible wiring board pieces 10, 30 are laminated.

For example, flexible wiring board pieces 30 each having thermoplastic resin film 33 may be bonded to form a multilayer flexible wiring board. In this case as shown in Fig. 6(a), two flexible wiring board pieces 30<sub>a</sub>, 30<sub>b</sub> are superposed in such a manner 15 that base film 12 of one flexible wiring board piece 30<sub>a</sub> comes into close contact with resin film 33 of the other flexible wiring board piece 30<sub>b</sub>, and said ultrasonic resonator 45 is pressed against contact regions 18<sub>1</sub> in contact with each other to apply ultrasonic wave under pressure, whereby a multilayer flexible wiring board 20 51 as shown in Fig. 6(b) is obtained.

In this case, opening 15 of one flexible wiring board piece 30<sub>a</sub> serves as a concave, while contact region 18<sub>1</sub> of the other flexible wiring board piece 30<sub>b</sub> serves as a convex member. Contact region 18<sub>1</sub> serving as a convex member is smaller than opening 15 25 serving as a concave so that base film 12 at the periphery of opening

15 serves to readily guide convex contact region 18<sub>1</sub> into opening 15 to facilitate aligning between flexible wiring board pieces 30<sub>a</sub>, 30<sub>b</sub>.

Alternatively, a thermoplastic resin film may be provided 5 on flexible wiring board piece 10 shown in Fig. 1(g) to prepare a multilayer flexible wiring board.

The references 20<sub>a</sub>, 20<sub>b</sub> in Fig. 7 represent such flexible wiring board pieces, in which a thermoplastic resin film 39 is formed 10 on base film 12 of flexible wiring board piece 10 shown in Fig. 1(g). Resin film 39 is patterned and opening 15 in base film 12 is etched to expose metal coating 26 at the bottom of opening 15.

In these flexible boards 20<sub>a</sub>, 20<sub>b</sub>, contact region 18<sub>1</sub> of one flexible wiring board piece 20<sub>a</sub> is smaller than opening 15 of the other flexible wiring board piece 20<sub>b</sub>. Therefore, convex contact 15 region 18<sub>1</sub> of one flexible wiring board piece 20<sub>a</sub> is forced into a concave formed by opening 15 of the other flexible wiring board piece 20<sub>b</sub> to connect contact regions 18<sub>1</sub>.

When ultrasonic resonator 45 is pressed against the top of contact regions 18<sub>1</sub> as such to apply ultrasonic wave to heat flexible 20 wiring board pieces 20<sub>a</sub>, 20<sub>b</sub> under pressure on contact regions 18<sub>1</sub>, metal coatings 26 on the surfaces of contact regions 18<sub>1</sub> are bonded together by ultrasonic vibration, and base films 12 are connected via resin film 39, whereby a multilayer flexible wiring board 52 as shown in Fig. 7(b) is obtained.

25 Although two flexible wiring board pieces were connected in

the foregoing examples, a multilayer flexible wiring board prepared by laminating three or more flexible wiring board pieces is also included in the present invention.

Although a polyimide adhesive was used for thermoplastic resin films 33, 39 in the foregoing examples, the present invention is not limited to this material but also includes the use of resins other than polyimide adhesives such as epoxy adhesives (such as A100 made by Sony Chemicals Corp.).

Metal coating 26 is not limited to a coating based on gold, but may also be a coating based on silver, a coating based on nickel, a copper-nickel alloy coating or a solder coating. Good connection is obtained when the same type metal coating is formed on two flexible wiring board pieces to be laminated.

For bonding, ultrasonic wave may be applied with an ultrasonic resonator directly pressed against the metal wiring body at the contact region or the metal coating formed on the surface thereof. If a plurality of contact regions is to be ultrasonically bonded, an ultrasonic resonator may be individually pressed against the contact regions to apply ultrasonic wave under pressure.

Although a process for applying ultrasonic wave to metal wirings by contacting the tip of an ultrasonic resonator and then applying ultrasonic wave is described above, the present invention is not limited to this process, but also a process for contacting the tip of ultrasonic resonator with metal wirings while applying ultrasonic wave to the tip of ultrasonic resonator.

According to the present invention, bumpless ultrasonic bonding is simplify the process.

Contact regions have a uniformity of height to reduce connection failure.

**WHAT IS CLAIMED IS:**

1. A process for manufacturing a multilayer flexible wiring board by laminating at least two flexible wiring board pieces having  
5 a base film including a resin film and a metal wiring provided on said base film, said process comprising applying ultrasonic wave to said metal wirings of said flexible wiring board pieces to be laminated in close contact with each other at their surfaces to bond said metal wirings.

10

15

2. A process for manufacturing a multilayer flexible wiring board by bonding metal wirings of at least two flexible wiring board pieces having a base film including a resin film and a metal wiring provided on said base film, said process comprising contacting the tip of ultrasonic resonator with the exposed opposite side of a portion to be bonded of said metal wirings of at least one flexible wiring board piece in two flexible wiring board pieces to be bonded, applying ultrasonic wave to said ultrasonic resonator to bond said two metal wirings to be bonded.

20

3. The process according to claim 1 wherein ultrasonic wave is applied to said metal wirings in close contact with each other at their surfaces while a thermoplastic resin layer developing adhesiveness upon heating is placed between said metal wirings.

25

4 . The process according to claim 3 wherein said metal wirings are ultrasonically bonded and then heated to laminate said flexible wiring board pieces by the adhesion of said thermoplastic resin.

5       5. The process according to claim 1 wherein a metal coating selected from a metal coating based on gold, a metal coating based on silver, a metal coating based on nickel, a copper-nickel alloy coating, a coating based on aluminium, a coating based on titanium and a solder coating is preliminarily formed on at least one of  
10      the surfaces of the parts of said metal wirings to be ultrasonically bonded before said metal wirings are ultrasonically bonded.

15       6. The process according to claim 1 wherein ultrasonic wave is individually applied to the parts of said metal wirings to be bonded.

7. A multilayer flexible wiring board formed by laminating at least two flexible wiring board pieces having a base film and a metal wiring provided on said base film, wherein at least one  
20      flexible wiring board piece has a cover film including a resin film on said metal wiring and a first opening is provided on said cover film, and said metal wiring exists at the bottom of said first opening so that said metal wirings of said flexible wiring board pieces are bonded to each other by applying ultrasonic wave while  
25      the part of said metal wiring located at the bottom of said first

opening is in close contact with said metal wiring of the other flexible wiring board piece.

8. The multilayer flexible wiring board according to claim  
5 7 wherein said cover film has insulating properties to prevent said connected metal wirings from contacting with each other except for the part located at said first opening.

9. The multilayer flexible wiring board according to claim  
10 8 wherein said cover film has a thermoplastic resin layer developing adhesiveness upon heating at least on its surface.

10. The multilayer flexible wiring board according to claim  
7 wherein said first opening and said metal wiring located at the  
15 bottom of said first opening form a concave, and the part of said metal wiring of the other flexible wiring board piece to be bonded to said concave forms convex on said base film.

11. The multilayer flexible wiring board according to claim  
20 10 wherein said convex part of said metal wiring of the other flexible wiring board piece has an area smaller than the area of said first opening forming said concave.

12. A multilayer flexible wiring board formed by laminating  
25 at least two flexible wiring board pieces having a base film and

a metal wiring provided on said base film, wherein said base film  
of at least one flexible wiring board piece has a second opening  
in which said metal wiring exists at the bottom so that said metal  
wirings are bonded to each other by applying ultrasonic wave while  
5 said metal wiring of the other flexible wiring board piece is in  
close contact with said metal wiring located at the bottom of said  
second opening.

13. The multilayer flexible wiring board according to claim  
10 12 wherein said base film has insulating properties to prevent said  
connected metal wirings from contacting with each other except for  
the part located at said second opening.

14. The multilayer flexible wiring board according to claim  
15 7 wherein at least one of the surfaces of the parts of said metal  
wirings to be ultrasonically bonded has a metal coating selected  
from a metal coating based on gold, a metal coating based on silver,  
a metal coating based on nickel, a copper-nickel alloy coating,  
a coating based on aluminium, a coating based on titanium and a  
20 solder coating.

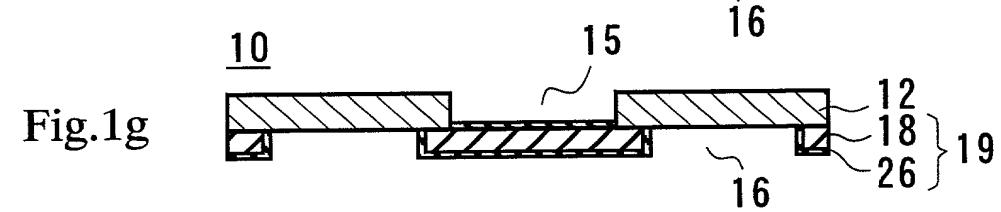
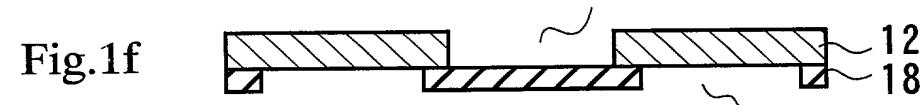
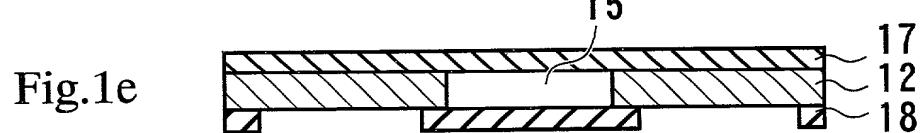
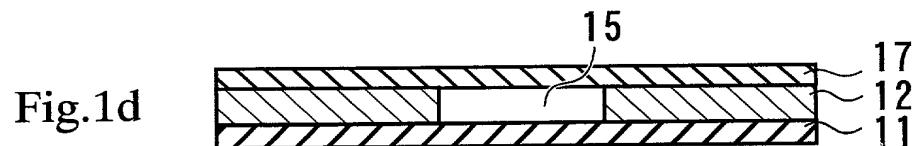
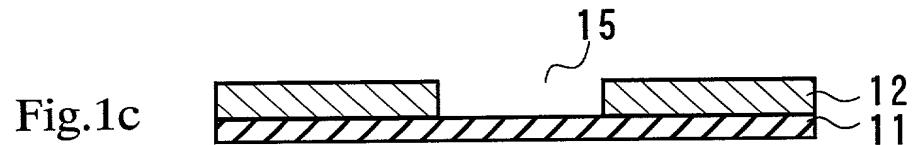
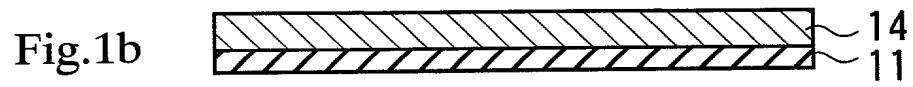
15. The multilayer flexible wiring board according to claim  
14 wherein said metal wirings to be bonded to each other have the  
same type metal coating on their surfaces.

## **ABSTRACT**

The present invention provides bumpless ultrasonic bonding of flexible wiring board pieces.

5       A metal coating 26 is formed on the surface of a contact region 18<sub>1</sub> of a metal wiring 28 of each of two flexible wiring board pieces 10, 30 and ultrasonic wave is individually applied by an ultrasonic resonator 45 to the contact regions 18<sub>1</sub> in contact with each other. The metal coatings 26 are bonded to form a multilayer flexible wiring 10 board 50. The bumpless process eliminates any plating step for forming bumps without being influenced by non-uniformity bump height. A thermoplastic resin film 33 may be formed on the surface of one flexible wiring board piece 30 to bond flexible wiring board pieces 10, 30 by the adhesion of the resin film 33.

15



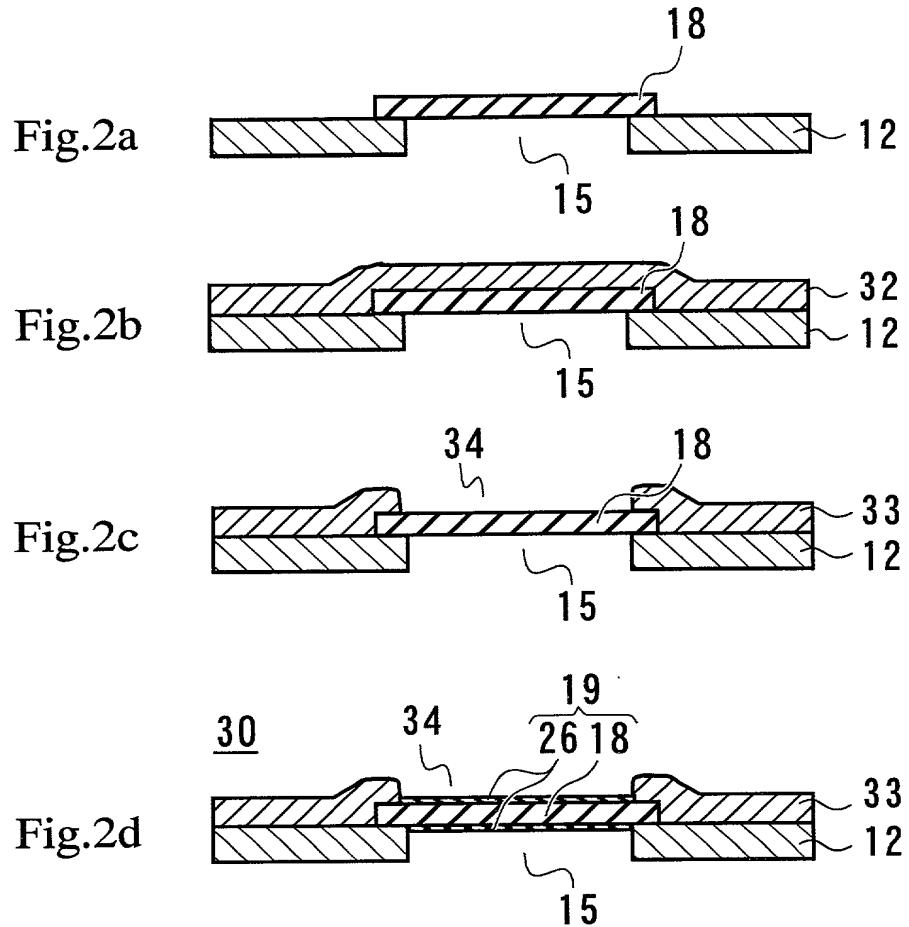


Fig.3a

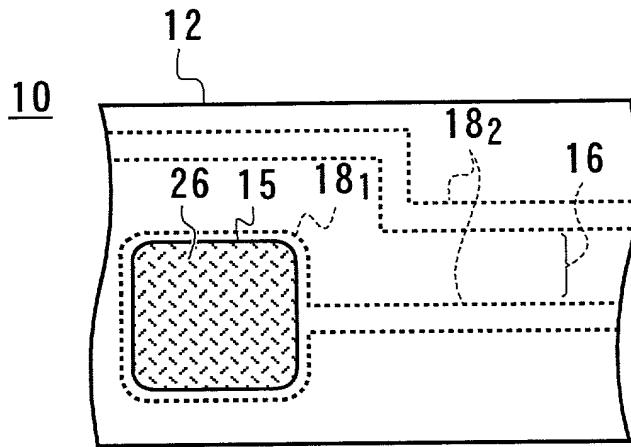


Fig.3b

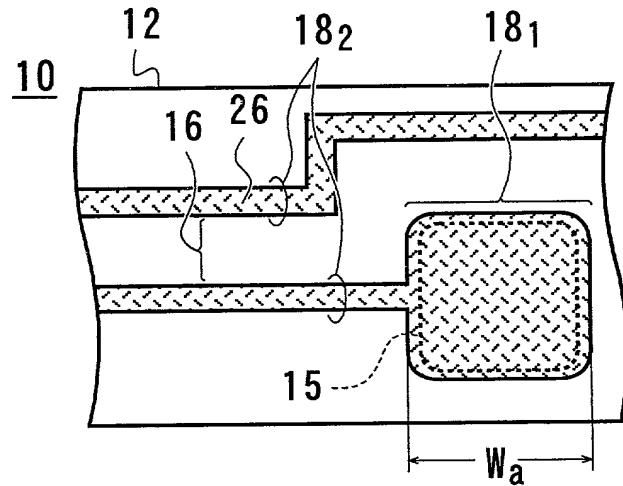


Fig.4a

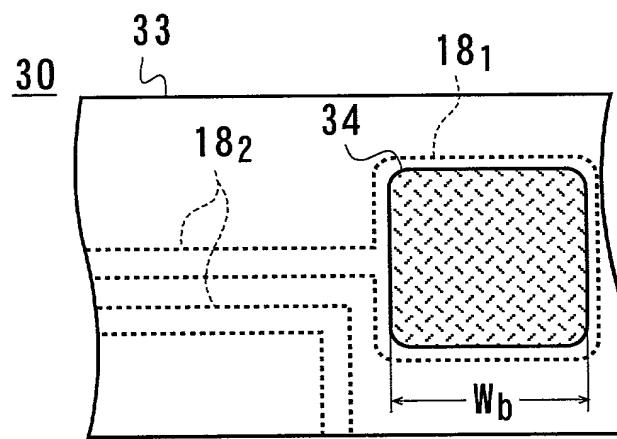
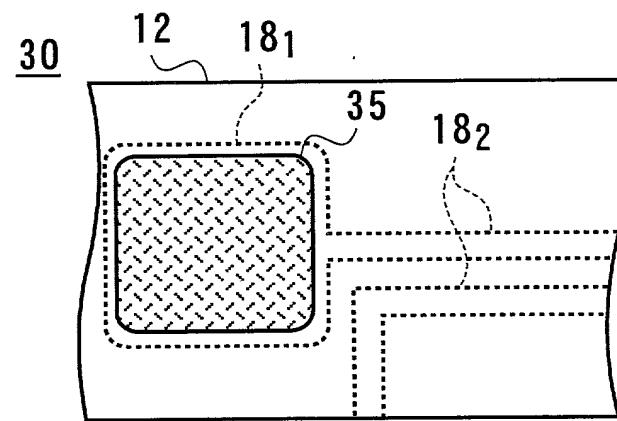
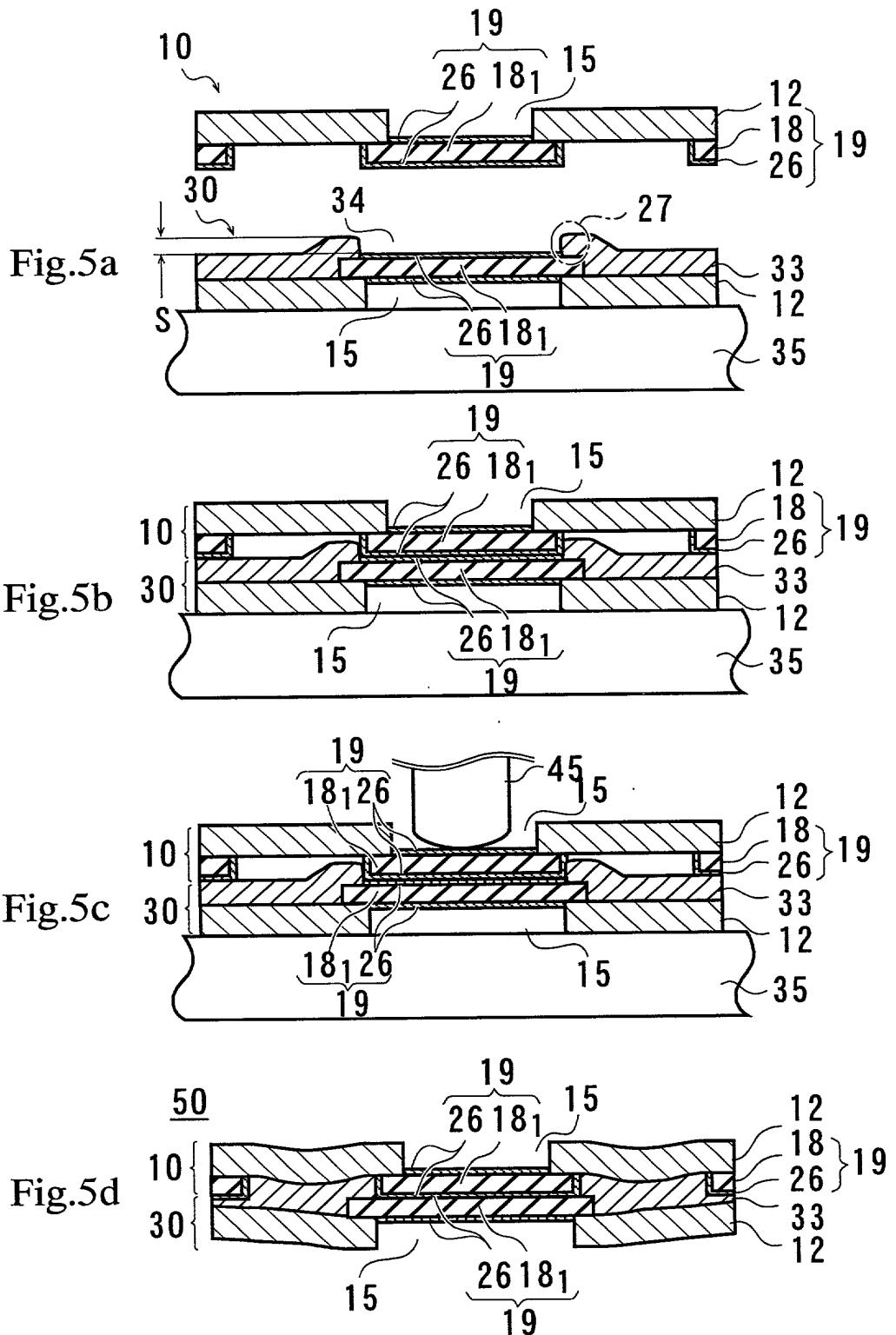


Fig.4b





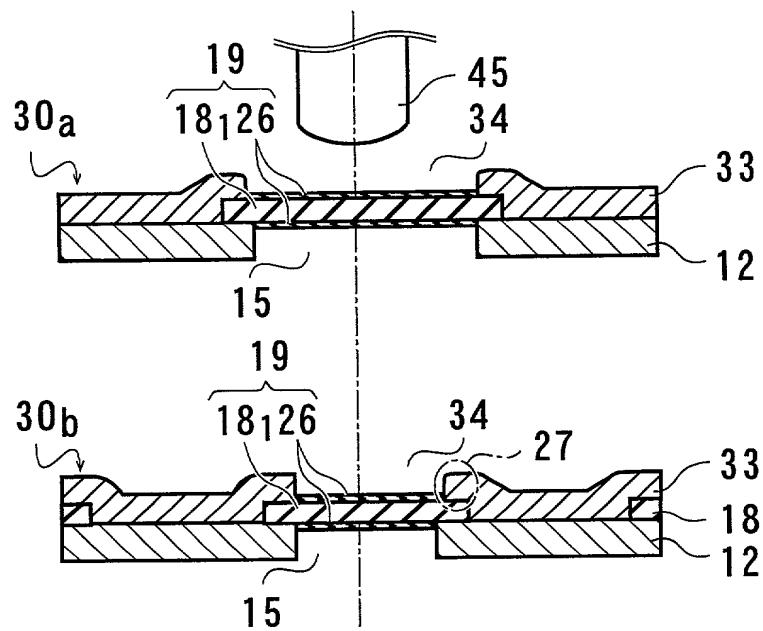


Fig.6a

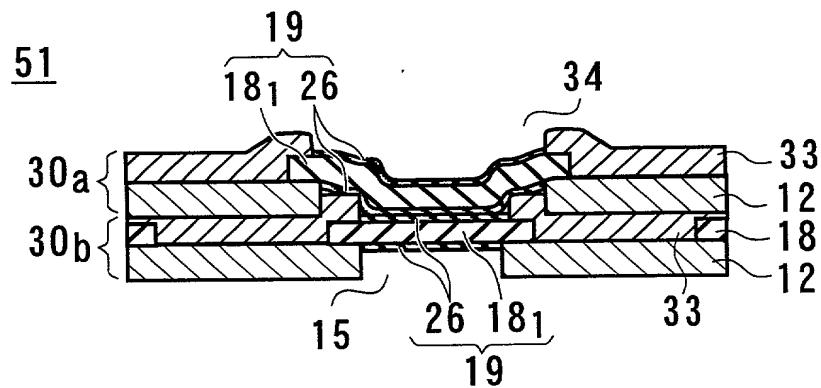


Fig.6b

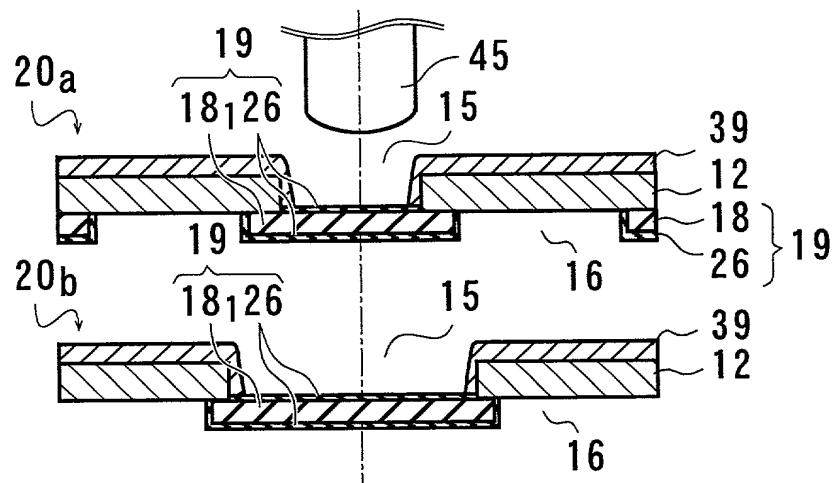


Fig.7a

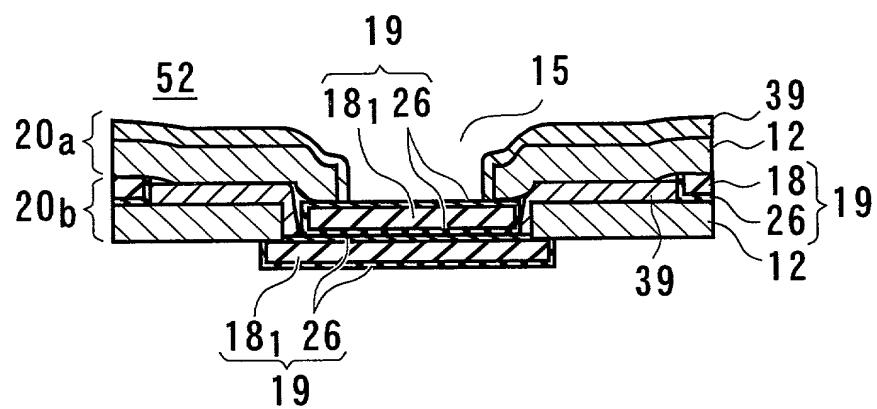


Fig.7b

Fig.8

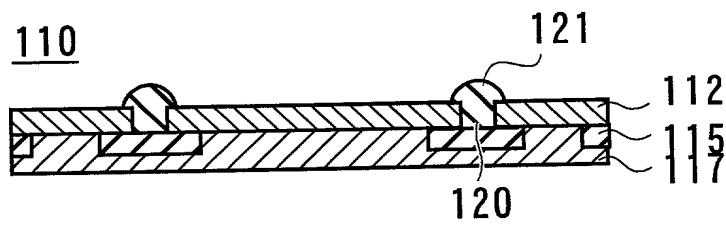
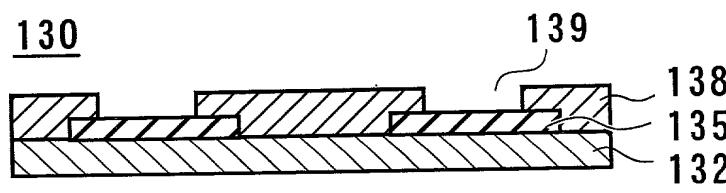
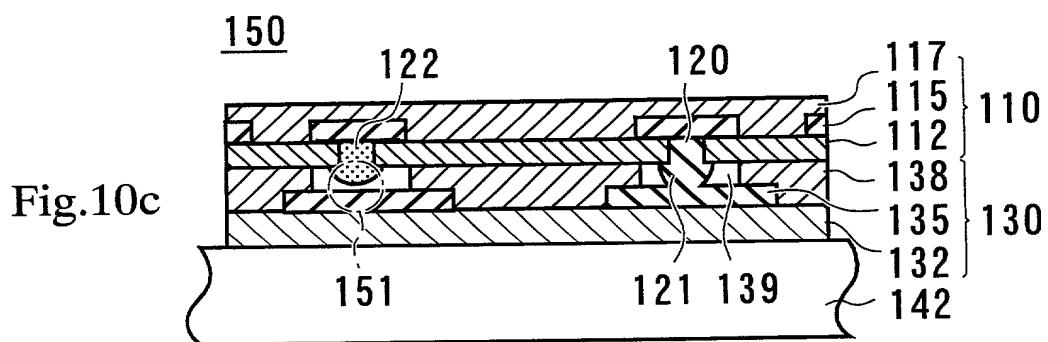
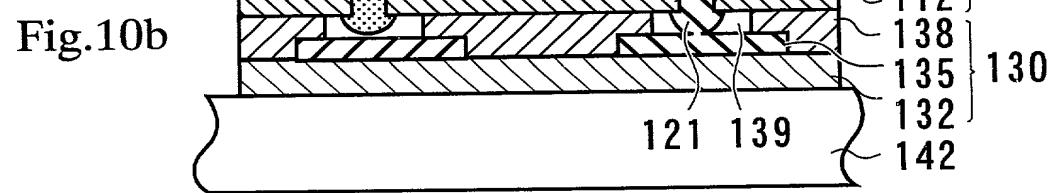
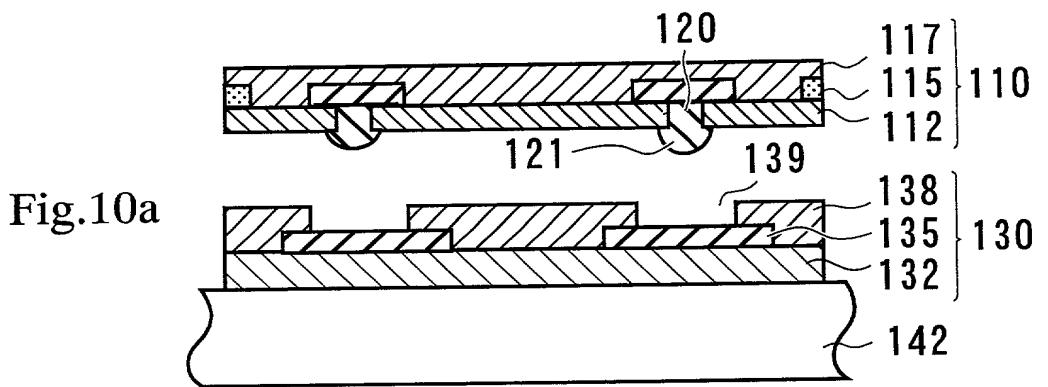


Fig.9





**APPLICATION FOR UNITED STATES PATENT  
DECLARATION AND POWER OF ATTORNEY**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: \_\_\_\_\_

~~MULTILAYER FLEXIBLE WIRING BOARDS AND PROCESSES FOR MANUFACTURING MULTILAYER FLEXIBLE  
described and claimed in the specification:  
WIRING BOARDS~~

Check one

- \*a.  attached hereto.
- b.  filed on \_\_\_\_\_ as Application No. \_\_\_\_\_ and amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

Under Title 35, U.S. Code §119, the priority benefits of the following foreign application(s) and/or United States provisional application(s) filed within one year prior to this application are hereby claimed:

Japanese Patent Application No. 11-294686 filed October 18, 1999

The following application(s) for patent or inventor's certificate on this invention were filed in countries foreign to the United States of America either (a) more than one year prior to this application, or (b) before the filing date of the above-named foreign priority application(s) and/or United States provisional application(s):

I hereby appoint the following as my attorneys of record with full power of substitution and revocation to prosecute this application and to transact all business in the Patent Office:

James A. Oliff, Reg. No. 27,075; William P. Berridge, Reg. No. 30,024;  
Kirk M. Hudson, Reg. No. 27,562; Thomas J. Pardini, Reg. No. 30,411;  
Edward P. Walker, Reg. No. 31,450; Robert A. Miller, Reg. No. 32,771 and  
Mario A. Costantino, Reg. No. 33,565.

**ALL CORRESPONDENCE IN CONNECTION WITH THIS APPLICATION SHOULD BE SENT TO OLIFF & BERRIDGE,  
PLC, P.O. BOX 19928, ALEXANDRIA, VIRGINIA 22320, TELEPHONE (703) 836-6400.**

I hereby declare that I have reviewed and understand the contents of this Declaration, and that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

|   |  |  |                |       |
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| 2 | **Inventor's Signature:  | Given Name   | Middle Initial |       |
| 3 | **Date of Signature:   | <i>Hideyuki</i>  | Family Name    |       |
|   |  | 5  | 16             |       |
|   |  |  | 2000           |       |
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|   | City   | State or Province  | Country        |       |
|   | JAPANESE   |  |                |       |
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\*If Box (a.) is checked, this form may be executed only when attached to the specification (including claims).

\*\*Note to Inventor: Please sign name exactly as it appears above and insert actual date of signing.

**IF THERE IS MORE THAN ONE INVENTOR USE PAGE 2 AND PLACE AN "X" HERE**

(Discard this page in a sole inventor application)

|  |  |  |                   |                |                   |             |         |
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| 2  | <b>Inventor's Signature:</b>                       |  |                   |                |                   |             |         |
| 3  | <b>Date of Signature:</b>                          | Month  | Day               | Year           |                   |             |         |
| Residence:   |  | City   | State or Province | Country        |                   |             |         |
| Citizenship:   |  |  |                   |                |                   |             |         |
| Post Office Address:<br>(Insert complete mailing address, including country) |  |  |                   |                |                   |             |         |
| 1  | <b>Typewritten Full Name<br/>of Joint Inventor</b> | Given Name   | Middle Initial    | Family Name    |                   |             |         |
| 2  | <b>Inventor's Signature:</b>                       |  |                   |                |                   |             |         |
| 3  | <b>Date of Signature:</b>                          | Month  | Day               | Year           |                   |             |         |
| Residence:   |  | City   | State or Province | Country        |                   |             |         |
| Citizenship:   |  |  |                   |                |                   |             |         |
| Post Office Address:<br>(Insert complete mailing address, including country) |  |  |                   |                |                   |             |         |
| 1  | <b>Typewritten Full Name<br/>of Joint Inventor</b> | Given Name   | Middle Initial    | Family Name    |                   |             |         |
| 2  | <b>Inventor's Signature:</b>                       |  |                   |                |                   |             |         |
| 3  | <b>Date of Signature:</b>                          | Month  | Day               | Year           |                   |             |         |
| Residence:   |  | City   | State or Province | Country        |                   |             |         |
| Citizenship:   |  |  |                   |                |                   |             |         |
| Post Office Address:<br>(Insert complete mailing address, including country) |  |  |                   |                |                   |             |         |

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